Diploma Thesis

Hygiene aspects throughout an eye camp in Nigeria, Africa

Submitted by

Katharina Johanna Kern

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Graz, 15.05.2025 *Katharina Johanna Kern m.p.*

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Zusammenfassung:

Einer der Hauptgründe für Erblindung in Entwicklungsländern ist die Katarakt-Erkrankung. Viele Menschen, die an dieser Krankheit leiden, haben keine Möglichkeit, einen Augenarzt oder eine Augenärztin aufzusuchen, und sind stattdessen weiterhin auf traditionelle Heiler beziehungsweise Heilerinnen angewiesen. Dabei werden immer noch gefährliche Verfahren, wie das Kataraktstechen durchgeführt, da die Patienten oder Patientinnen versuchen, zumindest ein wenig Sehvermögen zurückzugewinnen. Um die Situation zu verbessern, führt „Sehen ohne Grenzen", eine österreichische Non-Profit-Organisation, seit vielen Jahren kostenlose Kataraktoperationen in Entwicklungsländern durch. In den letzten Jahren fanden diese Eye-Camp-Projekte in Nigeria statt.
Diese Diplomarbeit beschäftigt sich aus dem Blickwinkel der Hygiene mit den Gegebenheiten des Augen-Camps 2023 in Nigeria.
Im Rahmen einer Beobachtungsstudie wurden die Rahmenbedingungen vor Ort, das Vorgehen und die Einhaltung der von der All India Society herausgegebenen „Task Force Guidelines to prevent intraocular infections and cluster outbreaks after cataract surgery" im präoperativen, operativen und postoperativen Setting evaluiert. Zur Beurteilung der Hygienequalität erfolgte die Entnahme von Wasserproben, Umgebungsproben und eine Auswertung der Ergebnisse von Augenabstrichen mit einem Fokus auf die postoperativ verabreichte lokale Gabe von Gentamycin.
Aufgrund der in Nigeria üblichen Wasserversorgung mittels Tiefenbrunnen wurden, umgelegt auf die österreichische Trinkwasserversorgung die zulässigen Grenzwerte für Koloniebildende Einheiten (CFU/ml) in vier von sechs Proben überschritten. Bei den Proben aus dem OP fand sich in 10 von 11 überprüften OP- Kassetten Keimwachstum, was zur Überprüfung des Sterilisationsgerätes führte.
Keiner der 40 Augenabstriche war steril, neben Keimen der physiologischen Haut- und Bindehautflora wurden auch Enterobacterales, Pseudomonadaceae und *Staphylococcus aureus* inklusive Methicillin-resistenter *Staphylopcoccus aureus* nachgewiesen. Als positiver Aspekt ist anzumerken, dass sich bei keinem der nachgewiesenen Erreger eine Resistenz gegen Gentamycin fand.
Was von ärztlicher Seite für ophthalmologische Eingriffe unter einfachen Bedingungen einzuhalten war, fand sich vollinhaltlich eingehalten.
In Feedback-Gesprächen wurden die kritischen Punkte thematisiert, entsprechende Maßnahmen ergriffen und/oder für zukünftige Augencamps vorgemerkt. Zusammengefasst

stellt die Arbeit des Teams von „Sehen ohne Grenzen“ einen immens wertvollen Beitrag zur Verbesserung der Situation von Katarakt-Patienten in Nigeria dar, was sich auch in der überaus unterstützenden Zusammenarbeit mit den Mitarbeitern und Mitarbeiterinnen vor Ort und der Dankbarkeit der Patienten und Patientinnen widerspiegelte.

Abstract:

One of the main causes of blindness in developing countries is cataract disease. Many people suffering from this condition have no access to an ophthalmologist and instead continue to rely on traditional healers. As a result, dangerous procedures, such as couching, are still being performed as patients attempt to regain at least some vision.

To improve this situation, "Sehen ohne Grenzen," an Austrian non-profit organization, has been performing free cataract surgeries in developing countries for many years. In recent years, these eye camp projects have taken place in Nigeria.

This thesis examines the conditions of the 2023 eye camp in Nigeria from a hygiene perspective. As part of an observational study, the local framework conditions, procedures, and compliance with the "Task Force Guidelines to Prevent Intraocular Infections and Cluster Outbreaks After Cataract Surgery," issued by the All India Society, were evaluated in preoperative, operative, and postoperative settings. To assess hygiene quality, water samples, environmental samples, and the results of ocular swabs were analyzed, with a particular focus on the postoperative local administration of gentamicin.

Due to the common water supply in Nigeria using deep wells, the permissible limits for colony-forming units (CFU/ml), based on Austrian drinking water standards, were exceeded in four out of six samples. In the operating room samples, microbial growth was detected in 10 out of 11 examined surgical cassettes, leading to a review of the sterilization equipment.

None of the 40 ocular swabs were sterile. In addition to physiological skin and conjunctival flora, Enterobacterales, Pseudomonadaceae, and *Staphylococcus aureus*—including methicillin-resistant *Staphylococcus aureus* (MRSA) were detected. A positive aspect to note is that none of the detected pathogens showed resistance to gentamicin. Regarding the medical requirements for ophthalmic procedures under simple conditions, all necessary standards were fully adhered to.

Critical issues were addressed in feedback discussions, and corresponding measures were implemented or noted for future eye camps. In summary, the work of the "Sehen ohne Grenzen" team represents an immensely valuable contribution to improving the situation of cataract patients in Nigeria. This was also reflected in the highly supportive collaboration with local staff and the gratitude of the patients.

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List of abbreviations

CFU- colony forming unit

WHO- world health organization

REV. FA. – Reverent Father

GDP- gross domestic product

AIOS- All India Ophthalmological society

ETO- ethylene oxide

CNS- coagulase negative Staphylococcus

MRSA- methicillin-resistant Staphylococcus aureus

SPP.– Species

Ps. aerug. – Pseudomonas Aeruginosa

E. coli – Escherichia coli

MALDI-TOF MS - Matrix-assisted laser desorption ionization–time of flight mass spectrometry

AMR - Antimicrobial Resistance

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1 Introduction

Vision is essential for people around the world. Especially in rural areas it is crucial to have a good eyesight to manage daily challenges. Due to the Cataract disease, people from all over the world are at risk of losing their vision and if affected, they try to find a solution to get back their eyesight, even if it involves couching, the dangerous practice of pushing the lens inside the vitreous body. Because many people cannot afford cataract surgery, practices like couching are still used at present day. Luckily, many ophthalmologists worldwide help to provide safe treatment for the cataract disease.

"Sehen ohne Grenzen" is an association that provides free cataract surgery in rural parts of the world. The practical part of this thesis has been organized through "Sehen ohne Grenzen" as part of their annual project in Nigeria, Africa.

Everything started in the late 1990s when Christoph Faschinger, an Austrian ophthalmologist, participated in an eye surgery camp in Papua New Guinea to help the people there. In the year 2000 he founded "Sehen ohne Grenzen" as a non-profit association. Since then, this association organized over 50 projects for cataract surgeries in countries all over the world. (Faschinger, o.D.)

In this thesis the hygienic conditions, under which the 2023s eye camp in Nigeria took place, are investigated. Hygienic standards in the Nigerian eye camp are compared to the AIOS guidelines for eye camps in rural areas. Surface samples from the operating theatre and the surrounding clinical rooms have been collected at the eye camp and got analyzed in Austria at the Hygienic Institute of MedUni Graz.

To assess the water quality in Nigeria, water samples of the hospital have been taken to the water laboratory of MedUni Graz and were analyzed there. The local Nigerian laboratory at the hospital has taken eye swabs of patients who did undergo cataract surgery during the eye camp and provided the results for this study. The Material collection and procession of the samples are explained in chapter 2. Chapter 3 comprises the results of the samples collected. To outline the results in a more practical way, tables and graphs have been compiled. The accomplishments of the eye camp in Nigeria and the results of the samples are discussed in chapter 4. The Appendix comprises pictures that have been taken in Nigeria to understand the situation better.

The following chapters describe the experimental part of this thesis that took place in Nigeria.

1.1 Cataract

1.1.1 What is it?

A cataract is the clouding or haziness of the eye's clear lens or its surrounding capsule, obstructing light from reaching the retina. This condition, which can impact people of all ages, is more prevalent among older individuals. It may affect one or both eyes and varies in its intensity. Initially, it progresses slowly without hindering daily tasks. However, as time passes, particularly beyond the age of forty or fifty, the cataract typically advances, leading to complete opacity of the lens and disrupting normal activities. Cataracts contribute significantly to global blindness. Treatment options involve using refractive glasses in the early stages. If the cataract significantly impairs daily activities, surgery becomes a highly effective option (Nizami & Gulani, 2022).

1.1.2 Pathogenesis of the cataract

The pathogenesis of a cataract is multifactorial, but the most common type is the senile form, which is age-related and often both eyes are affected. It also occurs as a congenital cataract which is related to infections during pregnancy or maternal nutrition. Unilateral cataracts of young people mostly occur due to traumatic injury, including perforating trauma, ultraviolet or ionizing radiation or injuries of the eye with chemicals. Systemic or endocrine diseases can also be drivers for cataract, such as diabetes mellitus. Previous eye diseases like chronic anterior uveitis or high myopia are also likely to cause the evolution of cataract. Lifestyle factors include Smoking, alcoholism, a poor nutrition or the intake of corticosteroids and anticholinesterase inhibitors (Nizami & Gulani, 2022).

1.1.3 Complications for patients

Due to a degenerative conversion of lens fibers and their proteins the lens itself loses transparency, leading to cataract formation. The vision of the patient becomes increasingly blurred and double vision occurs. As some parts of the lens are still normal and others are

already clouding when a cataract is formed colored halos around the light may emerge. Additionally, a disturbance in color vision is possible, which appears in the form of fading objects or objects turning yellow (Nizami & Gulani, 2022).

1.1.4 Examination of the cataract

A comprehensive ophthalmic examination involves several key assessments to evaluate the condition and plan appropriate management for cataracts:

1. **Visual Acuity:** Visual acuity assessment helps to determine the severity of the disease and its impact on daily life activities. It is typically done with tools like the Snellen chart.
2. **Refraction:** Refractive glasses are crucial for planning the appropriate management approach.
3. **Cover Test Significance:** The cover test assists in detecting any divergent squint, which may arise due to reduced vision caused by cataracts.
4. **Slit-lamp Examination:** This examination method allows for the following detailed assessments:
    1. **Pupillary Responses Check:** Checking pupillary responses involves observing the shape of the pupil, assessing afferent and efferent pathways, and detecting any relative afferent pupillary defect.
    2. **Adnexal Examination Significance:** Thorough examination of adnexal structures is necessary to rule out pathologies like dacryocystitis, blepharitis, or other conditions that may predispose individuals to complications during cataract treatment because these can lead to endophthalmitis.
    3. **Cornea Evaluation:** Assessing the cornea's ability to withstand surgical trauma is essential, especially noting arcus senilis, which could obstruct the clarity of the surgical field (Nizami & Gulani, 2022).

1.1.5 Cataract interventions Nigeria

Extraction of the blurred lens and replacement with an artificial lens is the common practice to treat cataract in western countries, such as Austria. Due to the lack of capable ophthalmologists in Nigeria and many other countries a traditional treatment of the cataract has been developed. Local healers practice the so-called couching. This procedure involves pushing the lens into the vitreous body with the help of a sharp instrument. Needles or thorns are used by the healers. According to the study in Sokoto the trends in couching are decreasing but, in the year of 2016, still 45,8 percent of cataract patients have undergone a couching intervention. Back in 2005 the majority of the patients (87,5%) had been couched (Asuquo & et al., 2014).

A study of southwest Nigeria shows that 96% of the patients remain blind after the couching procedure. 70% of the patients in this study had severe complications after couching, such as retinal detachment, glaucoma, cornea opacity or optic atrophy.

Several reasons push people to still undergo a couching procedure. Cost is the main factor for not undergoing cataract surgery. Other barriers are the denial of family members to escort patients to surgery, the refusal of treatment at an eye care facility or the ignorance of existing alternatives like surgery. For people who live in rural areas, it is also easier to contact a traditional healer than an eye care facility. Figure 1 shows the availability of health facilities in Nigeria.

Although the prevalence of cataract is higher in women, 54,2% of the operated individuals in this study were male. Women are less likely to receive a cataract intervention according to a study in Sokoto (Muhammad & et al., 2017).

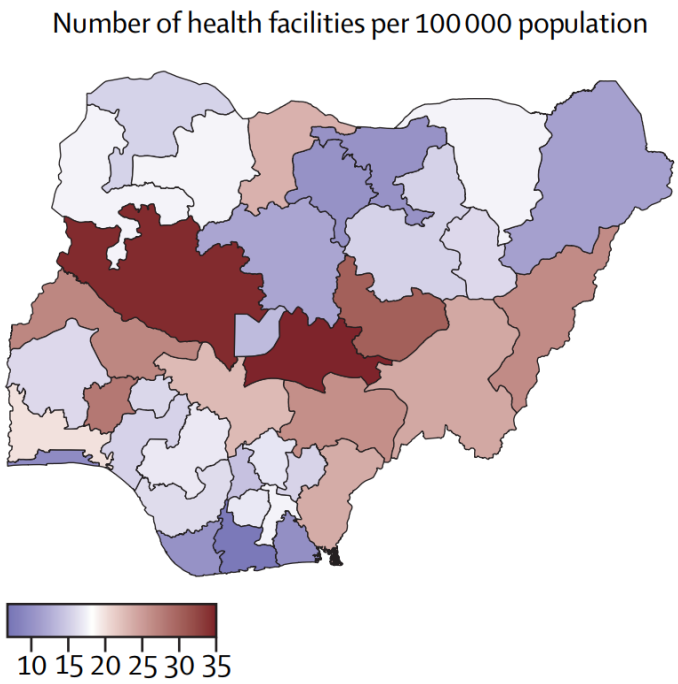


Figure 1 Number of health facilities per 100000 inhabitants Nigeria, (Muhammad & et al., 2017)

1.2 Facts about Nigeria

1.2.1 Population

Nigeria is by far the most populated country in all Africa. With more than 216 million inhabitants (2022) it is the sixth most populated country in the world. By 2050, Nigeria is predicted to have 410 million inhabitants. This massive population growth is caused by a very high fertility rate. Women in Nigeria bear 5,7 children on average while the average worldwide lies with 2,5 kids per woman. (Nigeria?, 2024)

Before being colonized by the British Empire, many different local kingdoms have existed. Today the biggest ethnical groups are the Igbo in the South, together with the Yoruba in the South-West and the Hausa group up North. English is the main language for communication which all ethnical groups can speak, but more than 500 different languages are spoken by all the different groups as a mother tongue. Nigeria´s population is also very young. 43,7% of the inhabitants are below the age of 15 years. However, life expectancy is very low with only 61 for men and 64 for women. In comparison the average life expectancy is estimated 73,4 years worldwide. The WHO has uploaded more detailed information about population distribution in Nigeria which is shown in Figure 2.

Although Nigeria has the highest GDP of all African countries, the wealth distribution is not equal. More than 40 percent of the population lives in acute poverty. The GDP per capita is estimated to be 2361 dollars per year. With a fast-growing population and a non-existing general governmental health care system, health care problems are a major concern in this country. Being the most populated state on the African continent, it would be crucial to take action to improve the health care system for its' people.
A study that took place in Sokoto, a state in the northern part of the country, showed that the presence of local ophthalmologists is very low and increases only very slowly. In 2005 Sokoto had no ophthalmologist, while in 2014 the number of practicing ophthalmologists increased to six. In theory a single ophthalmologist is responsible for over 800 000 patients (Abubakar & et al., 2022) (Muhammad & et al., 2017) (n. a., 2024) (n. a., 2024)!

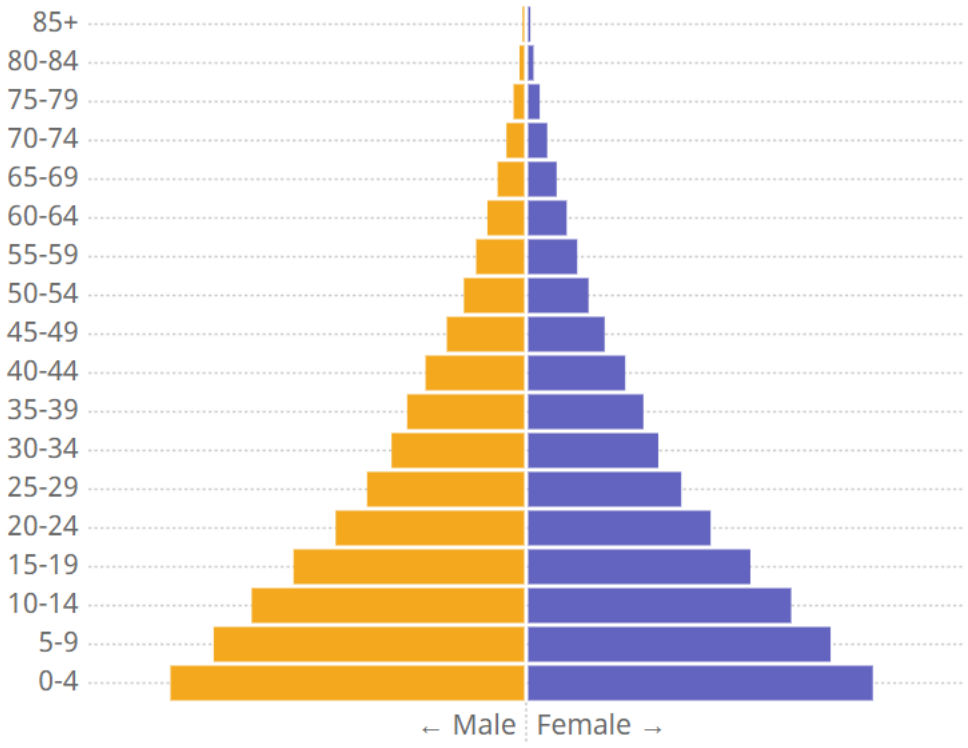


Figure 2 Population distribution by age and sex of Nigeria 2020, (https://data.who.int/countries/566)

1.2.2 Imo State and Madonna Austrian Hospital

Imo State is the home of Reverent Father Dr. Emeka Emeakaroha, the founder of Madonna Austrian Hospital. This state is located in the South of Nigeria, next to Rivers state, which contains the biggest City in this region, Port Harcourt. This is also the location of the closest international airport. The Madonna Austrian hospital is located in the village of Ihitte-Uboma, where Rev. Fa. Dr. Emeka Emeakaroha grew up. The closest city to acquire any material that is needed inside the hospital is Owerri which is about one hour by car. Owerri is also the capital of Imo state, and the dominating ethnical group are the Igbo. The Madonna Austrian Hospital is undoubtedly very important for the whole region because for people from rural parts of this or neighboring states there is no other option to receive professional health care. The hospital itself has been built in 2013 with donations from Austria. It is equipped with around 30 hospital beds and is run by the local sisterhood. Two local physicians and many nurses work at the hospital throughout the year. Operations rely on donations from Austria with Rev. Fa. Dr. Emeka Emeakaroha actively promoting the hospital and its services.
Every year Rev. Fa. Dr. Emeka Emeakaroha organizes a week of free health care for the local population to which we will refer to as the eye camp week. Doctors from Austria are invited to voluntarily work in the hospital to provide the necessary treatment for patients in the fields of Ophthalmology, pediatrics, and general surgery. This thesis is only focused on the ophthalmologic part (Emeakaroha, 2013).

1.2.3 Routine for patients at the eye camp

Prior to any clinical medical examination, local Nigerian doctors are searching the area around the village of Ihitte-Uboma for potential patients who would need a cataract surgery urgently. Those identified by the doctors are pleased to come to Madonna Austrian hospital for a first clinical examination. The patient's data are collected, and the maturity of the cataract is evaluated roughly. All the patients are called for the surgery when the Austrian ophthalmologists arrive in Nigeria. As much patients as possible will undergo surgery during one operation day.

On the exact day of surgery, the patient arrives at Madonna Austrian hospital at 8am. After the patient is identified by the Austrian team, he or she will receive Tropicamid 0,5% and

Cyclopentolat eye drops to accomplish a good cycloplegia. Phenylephrin 2,5% is added for the dilation of the pupil and to maximize the vision for the ophthalmologist during surgery because of the evoked vasoconstriction in the vessels of the conjunctiva. A further and more complex clinical examination is now performed. Using the slit lamp, a widespread documentation of both eyes' health status is done and the maturity of the cataract is defined. This is crucial for deciding on which operation method to choose. For more complicated situations tonometry is used additionally.
Now the patient is ready for local anesthesia. Ropivacain eye drops are inserted into the affected eye twice. The first time before measuring the axial length of the eye bulbus using ultrasound and a second time afterwards. To ensure disinfection of the bulbus surface Povidone iod in the form of eye drops are applied. After a few more minutes local anesthesia can be injected into the bulbus. Xylonest 0,5% 50ml and Ropivacain 10mg are used. Again, Povidone iod eye drops are put into use for disinfection and one drop of Tetracain is inserted additionally.

The patients are now brought into the operation theatre and are asked to wear a surgical cap and to take off their shoes. Two patients can be operated at the same time in one theatre. It is crucial to let the patients know that they should not touch anything sterilized. The skin around the eye is now cleaned with Betaisodona solution from the center to the eye periphery and a surgical cover is brought onto the patients' face. After a last test for touch sensation cataract surgery can be performed. It takes about 15 to 20 minutes.

Cataract surgery is always performed through a microscope to ensure precise work. Primarily, the surgeon makes a small incision into the cornea without hurting any other structures. Adrenaline is injected into the anterior chamber to ensure the best possible cycloplegia. Secondly, a viscous solution is brought into the anterior chamber to stabilize it. The anterior capsule of the lens is then incised to make way for extracting the cataract lens. The extraction itself is performed via phacoemulsification. Through this procedure the lens is grinded into small pieces via ultrasound and exhausted into the phacoemulsification machine. It is important to make sure that the posterior capsule of the lens is intact. Otherwise, the new intraocular lens is likely to fall into the vitreous body. The capsule is then filled with viscoelasticum again. Now the new intraocular lens is ready to be brought into the eye. The viscoelasticum is exhausted and the new lens is unfolding inside the capsule. No suture is needed, because the incision is small enough.

The operated eye is then covered with swabs and a plastic eye cover.

The next morning, the cover will be removed and a last examination will be done. The eye is cleaned and checked with a normal eye lamp. Finally, patients are advised on how to use antibiotic eye drops for the duration of about one week and receive diamox tablets in the case of increasing eye pressure.

1.2.4 Antimicrobial resistance in Nigeria

Due to the lack of fresh clean water and poverty around Nigeria, the expansion of microorganism is facilitated. These factors together with insufficient infection control also increase the risk of spreading resistant strains. According to Chinonyerem O. Iheanacho and Uchenna I. H. Eze hospital acquired infections and antibiotic treatment are a lot more common in low-income countries such as Nigeria than in European countries. The improper usage of antibiotics increases the risk of the development of antimicrobial resistances (Bale , et al., 2023). In 2022, governmental regulations for the usage and sale of antimicrobial substances are not present. Many substances are available to buy over the counter. This allows people to freely consume antibiotics according to their knowledge. (Chinonyerem O. Iheanacho and Uchenna I. H. Eze, antimicrobial resistance Nigeria). An increasing number of resistances lead to more difficulties in situations when antibiotic treatment is actually necessary. In serious cases, antibiotics become ineffective against resistant strains and can no longer be used and thereby reducing the number of functional antibiotics (Iheanacho & Eze, 2022).

1.2.5 Water supply in Nigeria

Nigeria does not have a governmental organized water supply. Most people depend on boreholes, hand-dug wells, water vendors, springs or in some cases public standpipes. At the same time the sanitation network is inadequate. Most households rely on pit latrines, septic tanks or open defecation with no wastewater or fecal sludge system available.

Shallow hand-dug wells are heavily affected by contamination through pit latrines or septic tanks. Boreholes are also affected but to a smaller degree.
A study of Kumpel et al. examined the water supply and quality of Port Harcourt in the Southern part of Nigeria. The city and its ‘surroundings are equipped with 10km of functional waterpipe network in 2013. Although 190km have been installed by the 1950s, but they have mostly become non-functional. In 2010, 85 percent of the household in Port Harcourt depended on boreholes as their main water supply. The study detected that 67 percent of the sampled population used different water sources for drinking and household activities. Almost all (96%) used the same water sources for their washing and cooking duties. Drinking water was mostly gathered from sachet or bottled water, which are both of better drinking water quality than borehole water.
The study detected thermotolerant coliforms as fecal indicator bacteria in 25 percent of all water samples collected. However, concentrations of fecal indicator bacteria in those samples were rather low, with only five percent exceeding the value of 100 cfu/100ml. In two percent of the samples both nitrate and fluoride had higher concentrations than the recommended levels with over 40mg/l and 1mg/l respectively. In 89 percent of the cases the pH was lower than 6,5 which could correlate with increasing corrosion of the supply material like well casings, pumps or pipes. Sachet water had the lowest results of thermotolerant coliforms with only 15 percent of the samples, while bottled water (26%), borehole (29%) or vended water (33%) had all higher concentrations. According to these findings, the majority of the population of Port Harcourt is instinctively using the best water for drinking that is available to them.
In terms of water storage, it is better to use elevated tanks over drums or buckets, as the results for fecal indicator bacteria were significantly lower (Kumpel & et al., 2016).

1.3 Hospital hygiene in general

1.3.1 Standards for assessing surface hygiene

Clinical wards and other furnishings are a good transmitter of bacteria for patients, if not cleaned properly. Bacteria are transmitted via staffs´ hands or equipment that touched the ward. When assessing surface hygiene, we must differentiate between surfaces of common

use, surfaces in an operating theatre and surfaces where food is processed. When evaluating the hygiene standards of surfaces for common use, measurements have to be taken before and after cleaning the investigated surface. The main goals are to identify indicator organisms that are related to high risk of infection for patients or to assess the quantity of any possible organism in a specific area. Indicator organisms are bacteria like staphylococci, including MRSA, Clostridium difficile, multiply resistant Gram-negative bacilli, Vancomycin resistant enterococci and Salmonella species. Hygiene standards for indicator organisms require less than one colony forming unit (CFU) per cm² on a surface for common use according to the study of S. J. Dancer. However, the total aerobic colony count, which is defined as the amount of aerobic living organisms within an investigated area must be less than 5 CFU/cm² by international standards. The same can be applied for hand contact surfaces. Counting more than 5 CFU/cm² on hand contact surfaces, risk of infection might be increased for patients (Dancer, 2004).

1.3.2 Operating theatre cleaning

According to the *South-West France Committee for the Fight against Nosocomial Infections* the operating theatre should be cleaned after every surgery. The floor should be mopped, all surfaces should be wiped with special attention to keyboards, anesthesiology equipment and video towers. A detergent and disinfection solution should be applied from top to bottom and clean to dirty to maximize the cleaning effect (Moszkowicz & et al., 2019).

1.4 Normal ocular microbiome

The investigation of the ocular microbiota can be performed with conjunctival swabs. Bacterial cultures are applied to identify different bacterial species. It is important to know, that there can be differences in the ocular microbiome of one eye to the other within the same human being. Chiang and Chern discovered that, of all the bacteria that are able to be cultivated, *Staphylococcus*, Propionibacterium spp., Diphtheroids, and *Staphylococcus aureus* were detected with the largest quantity. Out of all gram negative bacteria the most

numerous ones were Pseudomonas spp., Enterobacter spp., and *Escherichia coli*. Overall, gram positive bacteria outnumber gram negative ones. In general coagulase negative staphylococci were the ones most likely to be found in conjunctival swabs. In some cases, also fungi species were isolated. *Basidiomycota, Ascomycota* and species of Malassezia, *Rhodotorula, Davidiella, Aspergillus*, and *Alternaria*, have been found.

Statistically, some bacterial species are more prevalent in certain parts of the eye. Pseudomonas species are more likely to be found on the conjunctiva fornix or the lid margin. On the other hand, *Acinetobacter, Aeribacillus* or Proteobacteria were mostly isolated from the ocular surface.
People who wear contact lenses tend to have an ocular microbiome that is more similar to the skin microbiome with species isolated like *Methylobacterium, Lactobacillus, Acinetobacter*, and *Pseudomonas*.
The ocular microbiome is highly sensitive to environmental and substantial influences. For example, it has been discovered that Proteobacteria occur more often in individuals having diabetes. Trauma, chronic alcoholism and previous antibiotic treatment are also listed as factors, which manipulate the ocular microbiome (Chiang & Chern, 2022).

2 Material and Methods

2.1 Data collection

As part of the eye camp, that took place in Nigeria in February 2023, the hygiene aspects have been investigated. The Austrian eye surgery team at the Madonna Austrian Hospital in Ihitte consisted of eight people – 3 experienced ophthalmologists and one resident for ophthalmology, 3 nurses and one technician. All of these colleagues originated from Vienna. To assess the hygienic aspects Prof. Grisold, an expert on Microbiology and Hygiene from Graz, was invited. As one of her students she took me with her to execute all the practical work and write my thesis.

Within this thesis five different topics have been examined: The first task was to compare the hygiene standards of the eye camp in Nigeria with a publication of AIOS Task Force guidelines for developing countries. (Lalit & et. al., 2022) Secondly, an analysis was conducted of the microbiological results of eye swabs taken by local doctors prior to the

eye camp. The same patients later received a cataract surgery during the eye camp. Thirdly, water samples have been collected from the hospital's faucets to determine the local water quality. Fourthly, surface samples have been collected inside the operating theatre and the examination rooms. Finally, swabs of the sterilizer have been taken. All the mentioned methods will now be described more precisely down below.

2.2 AIOS Task Force guidelines

The task force guidelines aim to prevent intraocular infections and cluster outbreaks after cataract surgery. They contain a list of recommended actions that should be followed during cataract surgeries even in difficult working environments. The guidelines are divided into four main parts.

- Preoperative measures
- Operative measures
- Postoperative measures
- Disinfection and sterilization of the operating theatre

The first part – the preoperative measures – focuses on the right preparation of the situation and the patients. Key points are preexisting diseases and disinfection of the operating field including the patients' eyes and the surrounding environment. Operative measures refer mostly on the patients´ - and the surgeons´ hygiene and the utensils used during surgery. Within the postoperative measures, recommendations for the patients´ follow up and the wound care are listed. The part of disinfection and sterilization of the operating theatre contains all information about the recommendations for the facilities of the operating theatre and the usage of this room. (Lalit & et. al., 2022). The results of the comparison of the Nigerian standards with the AIOS Guidelines are listed in chapter 3.1.

2.3 Evaluation of eye swabs

All patients who are possible candidates for cataract surgery at the eye camp must undergo a first orientation examination. At this examination local Nigerian doctors investigate the general status of the patients and the state of the cataract. For this study, 40 eye swabs have been taken of random patients who are listed for cataract surgery in the eye camp. The swabs have all been taken from the conjunctiva of the lower eyelid. Standardized sterile swabs were used by the local staff and cultivated in the local laboratory. The results were

made available in anonymized form for the evaluation of the resistance rates and are presented in chapter 3.2.

2.4 Water sample collection Madonna Austrian Hospital

The hospital relies on a self-made borehole that is about 6-7m deep. The ground water is collected and pumped into four tanks that are placed on an elevated platform that is higher than the hospital itself to use the hydrostatical pressure for the water supply in the building. One tank can store about 5700 liters of water. No filtering system is installed, which means the water that is running out of the tap inside the building is natural ground water. The hospital staff cleans the tanks about three to four times a year. For that they use simple brushes. Inside the hospital building several sinks are installed for cleaning equipment, patient´s hygiene and drinking water.

As part of this thesis the water quality is assessed in at least five places of the hospital.

- The first sample was gathered next to the tanks outside of the hospital from an installed sink. This is the first option to discharge some water from the water pipeline (see figure …).
- A second sample has been acquired in a patient restroom on the ground floor after rinsing the faucet several minutes.
- The third testing took place on the second floor in the changing room of the eye operating theatre. The sink installed there is usually used for washing operational equipment. Once again, the sample has been taken after rinsing the faucet for 2 minutes.
- A fourth sample was taken from the third floor of the hospital. The sink in this toilet is the last passage of the waterway inside the hospital.
- The fifth and last sample has been taken from a second-floor toilet sink.

All samples were collected by the Austrian team on the last day of the eye camp to avoid bacterial growth. The water was filled inside standardized water collection bottles for the laboratory. All samples were later investigated by the water laboratory of the D&R Institute of Hygiene, Microbiology and Environmental Medicine, Medical University Graz using standardized methods. To cultivate bacteria, agar plates must be prepared using different methods: Some plates were prepared with the so-called pour plate technique. Some were created via the membrane filtration technique and some with the spread plate

technique. All different techniques were performed in a standardized way using the EN ISO 8199 norm (ISO e.V. (Hrsg.), 2018).

To cultivate different types of bacteria five different agar plate types had been used. Of all six original water bottle samples, 14 plate samples were created per bottle, so in total 84 agar plates have been incubated and analyzed. The methods to create the
14 plate samples are explained now for one bottle sample. All other five bottles were handled the same way.
Using the pour plate technique six plates were created. Two dilution series were prepared and incubated at two different temperatures. One milliliter of the water in the bottle has been pipetted into a sterile petri dish and mixed with 15ml of yeast extract agar. Next, 0.1ml has been pipetted into another sterile petri dish and again mixed with the yeast extract agar. A third plate was created with 0.01 ml of water and 15ml of yeast extract agar. This dilution series was than incubated at 22°C. Another three plates in the exact same dilution series were created and incubated at 37°C.
Using the membrane filtration system, four plates per bottle were created. A sample of 50ml water was filtered in a membrane filtration system and the filter was placed onto one of the four agar plates. This procedure has to be performed four times for each agar plate. The four types of agar plates differ in their constitution because some bacteria are easier to cultivate on different ground agars. Cetrimide agar is used to enhance pseudomonas growth. Slanetz and Bartley agar should activate the growth of E. coli and coliform enterococci. Columbia agar with 5% sheep blood is not selective in bacterial growth and chromogenic coliform agar is also used for E. coli and coliform bacteria.
The same four types of agar plates are also used for the third technique. Via the spread plate technique 250 microliters of water of the original bottle were placed onto the four previously mentioned agar plates (Cetrimide, Slanetz, Blood agar and Chromogenic agar) and spread out onto the plate. All plates were incubated at standardized times for each procedure using the EN ISO 19458 norm (EN ISO e.V. (Hrsg.), 2006).

2.5 Collection of surface swabs

In total 29 surface swabs – respective dip slides - have been collected by the Austrian team. Inside the operating theatre 21 swabs were taken with special attention on sterile tables and the microscope.
Detailed description:

Two operating tables, each with one table for instruments, are installed inside the operating theatre. One additional table with sterile cover is placed behind the surgeons. For each operating table four swabs were taken from the bedhead of the operating table. Five dipslides have been collected for each sterile side table for instruments. At each headpart of the two microscopes one swab has been taken and one more swab at the backside table with sterile cover.

The rest of the samples have been collected in the antechamber of the operating theatre and the examination room. Inside the antechamber a side table used for material storage and food has been tested with one swab. The soap, used for washing operating equipment and bandages for the kids operating theatre have also undergone testing with one swab each. One last dipslide was used for a tub, used for washing operating instruments with a soap solution.

Inside the examination room places of frequent hand contact and important workplaces were investigated. One sample was taken from the side table, used for preparing local anesthesia. Another swab was collected from the touch screen of the ultrasound, utilized to measure the eye axis. The door handle and the first page of the clipboard for the operating planning were also tested with one swab each.

All swabs collected were brought to the microbiological laboratory of the Section Clinical microbiology and Hospital Hygiene at the MedUni Graz. After cultivation of the swabs, identification of the bacteria was carried out using a MALDI-TOF MS (matrix-assisted laser desorption ionization–time of flight mass spectrometry) Biotyper (Bruker, Daltonik GmbH, Bremen, Germany. Resistance testing and interpretation was performed according to the actual EUCAST guidelines (European Committee on Antimicrobial Susceptibility Testing) (Kahlmeter, 2025). All results were examined by the Microbiological Laboratory Graz and are presented in chapter 3.4.

2.6 Collection of swabs of the sterilizer

The autoclave machines, used to sterilize the instruments for eye surgeries, have been tested for sterility with sterile swabs. Each surgeon had his own set of cases for the instruments. Four sterile cases of one surgeon and three sterile cases of another surgeon had been tested. Four more swabs have been collected from used cases to compare the results. The swabs have then been transported to Austria to be cultivated in the microbiological laboratory of the Section Clinical and Hospital Hygiene at MedUni Graz.

All swabs have been transmitted onto blood agar plates and incubated at 37°C. Colony forming units have been counted and analyzed after incubation. See chapter 0 for results.

3 Results

3.1 Results Comparison with AIOS Task Force Guidelines

Nigerian standards have been compared to the AIOS Task Force guidelines and the results are presented below.

3.1.1 Preoperative measures

Due to the AIOS task force guidelines, patients with reduced systemic immunity are more likely to acquire an intraocular infection. Therefore, it is crucial to examine whether the cataract patients were diagnosed with diseases like diabetes mellitus or hypertension before. Local Nigerian doctors examine the potential cataract patients in the weeks before the eye camp.
Following these recommendations, it is clearly noted by the local staff on the examination sheet, if a patient has diabetes or hypertension.

The local doctors also perform the first ocular examination, estimate the maturity of the cataract and note a recommended type of surgery. They also check for local infections of the lid, the adnexa and the lacrimal system as recommended by the AIOS guidelines.
On the day of operation, another examination of the eye is performed by the Austrian doctors. Once again, the general health status is assessed, and the eyes and their adnexal organs are investigated for infections. To characterize the cataract more precisely, the slit lamp is used. If necessary, contact procedures like biometry or tonometry are performed within this examination. However, the AIOS guidelines would not recommend using contact procedures like tonometry on the operation day to minimize infection risk.
According to international guidelines and studies, there is no evidence to prevent postoperative infections with the help of topical antibiotics beforehand. Accordingly, preoperative topical antibiotics are not commonly used in the eye camp in Nigeria. On the other hand, Povidone Iodine 5% is an absolute must. At the eye camp in Nigeria, it is used twice with a minimum contact time of three minutes.

According to the AIOS, several rules for mass surgery should be performed at all times. Not more than 25 eyes should be operated by one surgeon within a timeframe of four hours. This is the case at the eye camp where approximately four eyes are operated during a four-hour period. At the Nigerian eye camp, two surgeons are working at the same time. Both are very experienced surgeons, and high-risk surgeries are always done by the most experienced one. Patients with multiple systemic diseases should be postponed for cataract surgery. The eye camp generally tries to operate younger healthy patients who benefit from the surgery the most. As far as possible, due to precautions, mono-ocular patients are listed early on the operating list, as recommended by the AIOS. At the Madonna Austrian Hospital, which is where the eye camp takes place, one operating theatre is only dedicated for eye surgery. No other surgeries are done in this room, like the AIOS suggests too. The Austrian Ophthalmologists check every operated eye the following morning. As soon as the Austrian doctors leave Nigeria, local doctors are responsible for emergency services. These should be available for one week minimum. Overall, the Nigerian eye camp fulfils the AIOS task force guidelines´ recommendations.

3.1.2 Operative measures

A written informed consent in the patients´ language must be signed by the patients or their relatives. As English is the main language in Nigeria, the informed consent is available in English. All information about the surgery is explained in English or the local language by a local nurse as well.
The operating theatre itself is equipped with two operating beds which are standing parallel to each other, and operating microscopes are installed at the head end of the beds. Before the operation starts, the patient and the eye designated for surgery are identified again. After that the eye is prepared through standard cleaning and draping protocols.

All surgeries are done under local anesthesia without the help of an anesthesiologist, who is not mandatory according to the AIOS. A basic life support trained technician should be available instead. During the time of the eye camp local doctors are always present and medical teams for general surgery and children's surgery are also there. Although recommended, a pulse oximeter is not used during local anesthesia operations. During the operation sterile drapes are the only equipment used to cover the patients. High risk patients should be supervised by an anesthesiologist or an extra doctor during operation

and an intravenous line should be maintained. This outreaches the capacity of the eye camp partly. Additional doctors are available, but intravenous lines are not commonly used. All obligatory drugs are prepared next to the surgeries, including emergency drugs.
The patients´ hygiene is another factor to keep an eye on. General information about hygiene after the surgery is provided by the local nurses in the patients' language of choice. Preoperative hygiene aspects, like taking a shower or general body cleaning are not followed by the patients. In general, head, hair and feet should be washed with soap and water before surgery. Patients wear their normal clothing from outside and do not undergo a specific cleaning protocol. For resource reasons, however, operation theatre dresses with caps and gowns cannot be provided.
Unusual congestion or discharge of the eye should be evaluated, and the operation should be rescheduled. Right before the surgery povidone iodine 5% is applied again to the periocular region and the eye. Sterile adhesive drapes and eye speculums are used as recommended in the guidelines of AIOS.

Surgeons and assistant staff also must follow certain regulations to minimize the patients´ infection risk: Anyone with fever, a systemic or local infection is not allowed to enter the operating theatre. At the eye camp in Nigeria in February 2023 all doctors and assistants were in good health condition. The number of people who enter the operating theatre is monitored at all times. Most of the time two surgeons together with two assistants were working inside the operating theatre with one or two additional local nurses that provide general help and support in case of language barriers. According to the AIOS guidelines viewing monitors must be placed outside the theatre. In Nigeria no viewing monitors exist, but due to the fact that two teams are working at the same time continuous monitoring of the patients´ state of health was ensured. The Austrian doctors also use specific footwear for the theatre as recommended. Shoes are changed when leaving the operating theatre as well as operating clothes, masks and gowns. Operating dresses are always provided for the staff working in the operating. Additional personnel are wearing sterile single-time usable gowns, caps and masks. Surgical washing and gloving are performed, as listed in standard protocols. Betadine or Chlorhexidine scrub should be used for hand scrubbing at least three minutes. Liquid soap is an alternative but must be used for a minimum of five minutes. All scrubbing should be performed with potable or purified water, which is not possible in Nigeria, instead tap water is used. Water sample quality tests have been taken and analyzed by the Austrian team. The results are available in chapter 3. For every new patient new

sterile gloves are used, prior to that hands are disinfected with chemical disinfectants, mainly alcohol-based. The guidelines also recommend that important does and don´ts should be listed and posted near the operating theatre. As the operating theatre is only used once a year for eye operations, these instructions were intentionally not posted.

Ringer lactate and balanced salt solutions are used as intraocular irrigating fluids in equal amounts during surgery although balanced salt solutions are preferred by the guideline. To avoid contamination of the irrigating fluids the following suggestions are mandatory. The batch number of all consumables should be noted, and the bottles of irrigating fluids should be preserved for at least 24h before discarding, to note eventual microbiological growth, visible as turbidity in the bottles. Both tasks are fulfilled in the Nigerian eye camp. For better visibility glass or plastic bottles should be used. Glass bottles should be checked for vacuum, with the vacuum test. The visibility is important because sediments or moving impurities can be identified inside of the fluid. All irrigation fluids in Nigeria are filled in plastic bottles.

Wounds generally do not need to be closed with sutures. Sutures only must be applied on high-risk patients and difficult cases with doubt about wound security. All intraocular instruments including the phaco tip, sleeve and cannula must be changed for every case, which is performed by the personnel in Nigeria. At the end of every operation, antibiotics can be used to prevent infection. At the eye camp, topical broad-spectrum antibiotics in the form of eye drops are instilled. Due to resource problems, e.g. no general washing of patients before surgery, not all AIOS recommendations can be fulfilled, but all medical requirements are abided.

3.1.3 Postoperative measures

After surgery, patients are informed by the next steps and all the precautions they have to follow. The eye is covered with an eye cup and patients get protective glasses after surgery. A nurse explains any further steps in the local language. The patients are advised to avoid eye rubbing and are told to return to the clinic the next morning to check the results. The first obligatory postoperative follow-up after 24 hours is performed the next morning. According to AIOS a slit lamp examination is also mandatory, but due to time constraints and the large number of patients that still needs to be operated on, it is regularly an only performed in case of suspicious eye findings. Additional follow-ups are optional

between three and seven days and 25-30 days after surgery. The Austrian doctors only stay for one week to attend the eye camp, further examinations are therefore not performed by them. Emergency cases are treated by local doctors at the hospital anytime due to its all-year operation. The AIOS Task Force guidelines only require a one-week consultation period for patients. If unusual pain or swelling occurs, patients are explained to see the doctor. Furthermore, they are shown how to apply topical antibiotics for seven to ten days and topical steroids for four to six weeks, as recommended. All postoperative findings and incidents are documented by the local staff. Postoperative recommendations are all fulfilled according to the AIOS guidelines.

3.1.4 Operating theatre disinfection and sterilization

The AIOS suggests that the operation theatre area should be arranged in a specific layout. It should contain an outer zone or protective zone, which exists in Nigeria as part of the waiting room for patients. A mid zone exists as well and serves as a changing room and transfer zone but at the same time functions as a disposal zone for auxiliary equipment. According to the AIOS the disposal zone should be separated, but due to lack of storage room additional equipment is stored inside the changing room in Nigeria. There is no specific aseptic zone where scrubbing and gowning takes place, but a designated area inside the changing room is used for that.

If an operating theatre is not used for more than three weeks, it is necessary to process three washings followed by fumigation and three consecutive negative cultures should be taken. Fumigation would not be necessary, if positive pressure ventilation exists. The eye operating theatre in the Madonna Austrian Hospital in Nigeria is only used during the eye camp week which takes place once a year in wintertime. Due to lack of resources, no positive pressure ventilation system inside the operating theatre could have been installed yet. The Austrian doctors clean the room and everything inside with disinfectant detergents like Sterilium® on the day of arrival. Fumigation equipment is also lacking. The next morning operations start.

Inside the operating theatre air conditioning is installed which allows to cool down the room. Recommend are 21°C, but due to the climate in Nigeria with temperatures reaching up to 40°C, that could not be accomplished at every moment. The humidity level would be

ideal around 55% but it can also not be measured in Nigeria. Window air conditioning is not used and would not be acceptable by AIOS. Filters used inside the air conditioning are recommended to be changed every week, which is not performed. Additionally, the air-condition and its´ equipment is to be cleaned every month with an according documentation. As the operating theater is only used one week each year, the air-conditioning inside the operating theatre is not being cleaned except for surface disinfection on the day of arrival of the eye camp team.

Daily cleaning should be performed on the floor, all surfaces, the operating bed and the microscope. The Nigerian staff is following this regulation. The walls cannot be cleaned as they are not tiled. An operating theatre should measure 130-160sq ft. (12-15m^2) to be suitable for four people working inside. Size standards are fulfilled in Nigeria.

The recommendations for disinfection and sterilization of the operating theatre are partly fulfilled. Due to a lack of time, the disinfection and cleaning protocols are only fulfilled on the day of arrival, but cannot include long term cleaning protocols beforehand. Additionally, cooling the operating theatre is another challenge because of the hot surrounding temperature in Nigeria.

3.1.5 Sterilization

The AIOS task force guidelines determine the most important facts about the Sterilization process under basic conditions. Sterilization of instruments is crucial for professional operation. Adequate sets of instruments should be prepared and available for every new case. Sterilization should be done by using an autoclave in between different patients. In general flash autoclave, plasma sterilizer or sterilization with ethylene oxide (ETO) are also acceptable. Chemical sterilization, formalin boxes or Cidex are not suggested. Furthermore, long tubes are best handled with an autoclave. Sterilization records are mandatory to perform. The Madonna Austrian hospital uses two autoclave machines by SciCan for sterilization that can host one full set of instruments which is used for one surgery. Statim 5000 is the exact name of the model of the autoclave machine.
It is important to check the autoclave machine and their results to achieve sterile instrument trays. The trays are checked for moisture or fluid remains after the sterilization process. In such a case the instrument tray must be sterilized again. The technician always

checks the trays after sterilization in Nigeria. Every one to three months biological indicator testing is recommended. Due to resource reasons, the autoclaves were checked upon arrival in the Nigerian hospital and test samples were gathered. Periodic or surprise checks are not performed although suggested. Bacterial cultures are to be performed every one to three months. Acceptable results after 30 minutes on 10cm blood agar plates that were kept open at the head end of the table are less than 10 colony counts with not a single gram-negative bacillus or fungal colony. This test has not been performed but some swabs have been taken and analyzed in the laboratory of Hygiene institute Graz. All detailed results can be read in chapter 3.4.

The recommendations by the AIOS could not be abided properly. The sterilizers have only been checked visually and by temperature control indicator. Microbiological testing were gathered in Nigeria but examined afterwards.

Figure 3 Sterilizer used in Nigeria

3.2 Results eye swabs

We received the results of the microbiological test results of 40 eye swabs and can evaluate and present them in this chapter.

As far as the bacterial load is concerned, one to four different bacterial types were found in each eye swab - none of the eye swabs remained sterile.

Aerobic Bacillacaeae have been isolated most frequently amongst the eye swabs. 35 out of 40 eye swab samples contained this type of bacteria.
The second largest group found in the samples can be assigned to the group of coagulase-negative staphylococci, which were detected in 29 out of 40 eye swabs. The most frequent representatives were *Staphylococcus epidermidis* and *Staphylococcus haemolyticus*.
Staphylococcus aureus was detected in seven eye swab samples and a further seven samples contained *Micrococcaceae*.
Nine out of 40 eye samples contained *Enterobacterales*, including *Morganella morganii*, *Enterobacter cloacae*, *Klebsiella pneumoniae* and *Proteus mirabilis*.
10 out of 40 Eye samples contained *Corynebacteriaceae*, viridans streptococci were found in six eye samples.
Enterococcus faecalis, *Comamonas aquatica*, *Pseudomonas aeruginosa* and *Acinetobacter pittii* were each detected only once in an eye swab sample.
The exact results of the various subgroups are shown in the graph below.

Table 1 Results Eye swabs

Number of positive Samples (n=40)	Pathogen group	Identified pathogens
35	Aerobic Bacillaceae	Aerobic Bacillaceae
29	Coagulase negative Staphylococci	*Staphylococcus epidermidis*, *Staphylococcus haemolyticus*
7	Coagulase positive Staphylococci	*Staphylococcus aureus* including 4 *Methicillin resistant S. aureus* (MRSA)
9	*Enterobacterales*	*Morganella morganii*, *Enterobacter cloacae, Klebsiella pneumoniae*, *Proteus mirabilis*
3	Nonfermenter group	*Comamonas aquatica, Pseudomonas aeruginosa, Acinetobacter*

		pittii
6	Viridans Streptococci	Viridans Streptococci
7	*Micrococcaceae*	*Micrococcaceae*
7	Corynebacteriae spp.	Corynebacteriae spp.
1	Enterococcus spp.	*Enterococci faecalis*

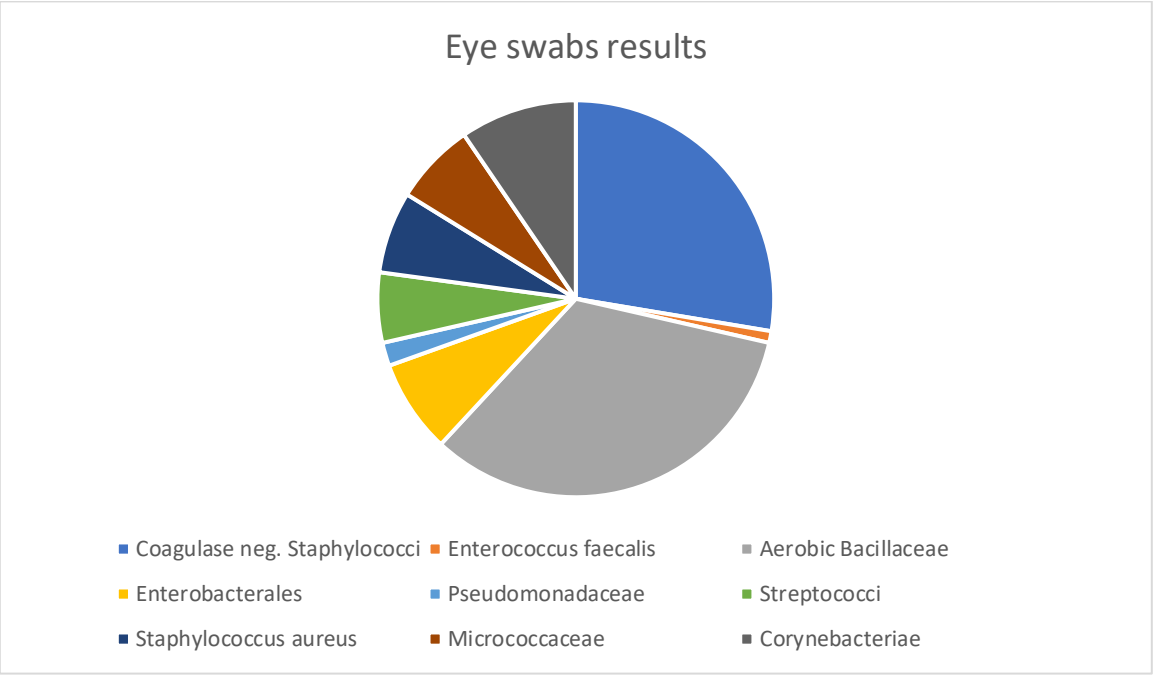


Figure 4 Diagram Results eye swabs

As seen more precisely in the diagram, Coagulase neg. Staphylococci and Aerobic Bacillaceae form the majority of bacterial types within the eye swabs.

As most of the identified bacteria are commensals of the normal eye flora, resistance testing was performed only for three of (potential pathogen) bacterial groups.
The three groups contain *Staphylococcus aureus*, *Enterobacterales* (with *Klebsiella pneumoniae, Enterobacter cloacae, Proteus mirabilis* and *Morganella morgagnii*) and Non- Fermenter (with *Comamonas aquatica, Pseudomonas aeruginosa* and *Acinetobacter pittii*).

The following graphs show the resistance (R) and susceptibility (S) of the bacteria within the different types of antibiotics. The number of individuals found of one species is listed below the species´ name.

The first graph contains *Staphylococcus aureus*. Four of the seven *Staphylococcus aureus* were resistant against Methicillin- so they are *Methicillin-resistant S. aureus* (MRSA). Since Gentamycin-containing eye ointment is used postoperatively, it should be noted that none of the tested *Staphylococcus aureus* showed resistance here.

Table 2 Resistance testing Staphylococcus aureus

Antibiotic	*Staphylococcus aureus* N= 7							Percentage of Resistance
	Resistance							
Penicillin/Ampicillin	R	R	R	R	R	R	R	100%
Amoxicillin/Clavulanic acid	R	R	S	R	R	S	S	57,1%
Cefoxitin	R	R	S	R	R	S	S	57,1%
Gentamycin	S	S	S	S	S	S	S	0%
Clindamycin	S	S	S	R	R	S	S	28,6%
Ciprofloxacin	R	S	R	R	R	S	S	57,1%
Tetracycline	S	R	R	R	S	S	S	42,9%

All of the tested Staphylococcus were susceptible to Gentamycin.

The next graph shows the results of the resistance testing of the family of *Enterobacterales*. This bacterial family contains *Klebsiella pneumoniae*, *Enterobacter cloacae, Proteus mirabilis, Morganella morganii* and E. coli. The number of individual bacteria tested are described with "N".

Table 3 Resistance testing Enterobacterales

Antibiotic	*Enterobacterales* N= 9					Percentage of resistance
Antibiotic	*E. coli* N=1	M. morg N=1	E. cloacae N=1	P. mirabilis N=4	K. pneumoniae N=2	
Ampicillin	R	R	R	S	R	55,5%
Amoxicillin/ Clavulanic acid	S	R	R	S	S	22,2%
Cefoxitin	S	R	R	S	S	22,2%
Gentamycin	S	S	S	S	S	0%
Trimethoprim/ Sulfamethoxazole	R	S	R	S	S	22,2%
Ciprofloxacin	R	S	S	S	S	11,1%

None of the *Enterobacterales* were resistant to Gentamycin at the resistance testing. Ampicillin had a resistance rate of 55,5% among the *Enterobacterales*.

Table 4 Resistance testing Nonfermenter

Antibiotic	Nonfermenter N=3			Percentage of resistance
Antibiotic	Comamonas spp. N=1	Acinetobacter pittii N=1	Ps. aeruginosa N=1	
Ampicillin	R	R	R	100%
Amoxicillin/ Clavulanic acid	S	R	R	66,7%
Cefoxitin	S	R	R	66,7%
Gentamycin	S	S	S	0%
Trimethoprim/ Sulfamethoazole	S	S	R	33,3%
Ciprofloxacin	S	S	S	0%

In the case of non-fermenters, the resistance rate to Ampicillin is 100 %. With a focus on Gentamycin, none of the isolates showed resistance here either, nor were any of the isolates resistant to Ciprofloxacin.

3.3 Results water samples

In total six water bottles have been transported to the water laboratory at the Institute of Hygiene, Microbiology and Environmental Medicine at MedUni Graz.
The samples have all been tested for colony forming units at 22°C and at 37°C. According to the Austrian standard of drinking water growth of *Escherichia coli*, coliforme bacteria, Enterococci and *Pseudomonas aeruginosa* the samples have been tested. The results are listed in Table 5 Water results for bacterial growth.

Table 5 Water results for bacterial growth

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
CFU/ml at 22°C	12	0	15	70	510	380
CFU/ml at 37°C	74	11	20	120	560	840
E. coli	0	0	0	0	0	0
Colifor. B	0	0	0	0	0	0
Enterococci	0	0	0	0	0	0
Ps. aerug.	0	0	0	0	0	0

The limit value for good water quality for colony forming units at 22°C is 100 CFU/ml. At 37°C the limit value is 20 CFU/ml.
Four out of six samples exceeded the permitted level of CFUs/ml.
Since none of the indicator bacteria could be detected, the bacteria were further identified using MaldiTof.
The results of the identification were: Growth of *Ralstonia pickettii, Cupriavidus pauculus, Delfia acidovorans, Achromobacter xylosoxidans, Chromobacterium violaceum*, Aerobic Bacillaceae and Micrococcus spp.

Sample number 1, number 4 and number 6 have undergone additional tests to determine the pH-value and electrolyte values.
All values for electrolytes have been in the normal range. The pH-values were acid and are shown in the table below.

Table 6 pH-values water results

	Sample 1	Sample 4	Sample 6
pH-value	4,49	4,46	4,76

3.4 Results surface samples

In total 29 surface samples were taken, whereas 18 samples (62,1%) remained sterile. Within the positive 11 surface samples, different bacterial species could have been detected. Table 7 Results surface samples shows one surface sample per row with its´ sampling location, the number of colony forming units (CFU) and the resulting germ

spectrum. Four out of 22 sample tests that should have been sterile were not sterile. These are listed as the first four sampling locations. Four bacterial species (*Acinetobacter haemolyticus*, *Staphylococcus aureus*, including MRSA and E. coli) have been complemented with resistance testing. These are listed in Table 8 Resistance testing surface .

Among the germs found, coagulase-negative Staphylococci (CNS), Aspergillus species and Micrococcus species formed the majority, with CNS in 10 out of 11 samples, Micrococcus species and Aspergillus species were detected 5 times.

Table 7 Results surface samples

Sampling Location	CFU/cm²	Germ spectrum
Bedhead operating table	7	Staph. aureus, CNS
Headpart microscope 1	1	CNS
Headpart microscope 2	52	*Aspergillus fumigatus & niger*, CNS, aerobic Bacillaceae
Backside table with sterile cover	5	Aerobic Bacillaceae, Micrococcus spp., CNS, *Aspergillus fum*., Fusarium spp.
Table antechamber	16	Aerobic Bacillaceae, Micrococcus spp., *Aspergillus fum*., Penicillium spp., Rhizomucor spp.
Bandages antechamber	20	Aspergillus spp., Cladosporium spp., CNS, Aerobic Bacillaceae
Soap antechamber	13	*Acinetobacter haemolyticus*, CNS, Micrococcus spp., E. coli
Touchscreen Ultrasound	24	*Aspergillus niger*, Fusarium spp., Cladosporium spp.,

		Micrococcus spp., CNS
Door handle examination room	1	CNS
Clipboard 1st page	13	Micrococcus spp., Aerobic Bacillaceae, CNS
Side table examination room	17	Cunninghamella spp., Curvularia spp., MRSA, CNS, Micrococcus spp.

The distribution of the germ spectrum is depicted in the following diagram. It is visible that CNS, Micrococcus spp., Aspergillus spp. and Aerobic Bacillaceae form the majority.

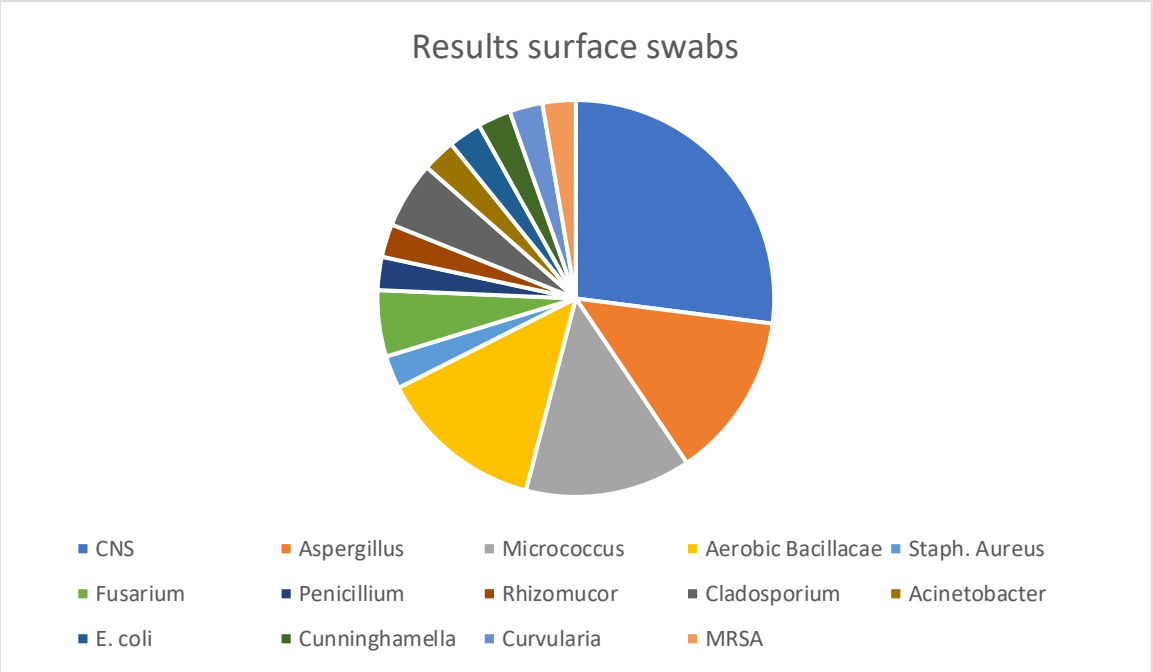


Figure 5 Results surface swabs

Table 8 Resistance testing surface samples

Antibiotic	Acinetobacter haemolyt.	Staph. aureus	S.aureus/ MRSA	E. coli
	n=1	n=1	n=1	n=1
Penicillin/Ampicillin	R	R	R	S
Amoxicillin/ Clavulanic acid	R	S	R	S
Cefoxitin	R	S	R	S

Gentamycin	S	S	S	S
Clindamycin	-	S	R	S
Trimethoprim/ Sulfamethoxazole	R	S	R	S
Ciprofloxacin	S	S	S	S
Fusidic acid		S	S	
Tetracyclin	R	S	S	R

As only one isolate per bacterial species could be detected in each case, the resistance testings are listed together. Again, no resistance to Gentamycin was detected in any of the isolates.

3.5 Results sterilizer

In total 11 swabs had been taken from the cases of the surgeon`s instruments - seven after the sterilization procedure, defined as “sterile”, four after using the cases during cataract surgery.

After the sterilization procedure only one case was in fact sterile. In four cases *Staphylococcus hominis* has been detected and in two other cases *Bacillus megaterium* has been found. The non-sterile cases after the surgery procedure also contained these two species of bacteria. In Table 9 Results swabs of the sterilizer” all results are shown in detail.

Table 9 Results swabs of the sterilizer

Sampling sterilizer	Pathogens detected
Case one “sterile” Surgeon A	sterile
Case two “sterile” Surgeon A	*Staphylococcus hominis*
Case three “sterile” Surgeon A	*Staphylococcus hominis*
Case four “sterile” Surgeon A	*Staphylococcus hominis*
Case five “sterile” Surgeon B	*Staphylococcus hominis*
Case six “sterile” Surgeon B	*Bacillus megaterium*
Case seven “sterile” Surgeon B	*Bacillus megaterium*
Case one non-sterile Surgeon A	*Staphylococcus hominis*
Case two non-sterile Surgeon B	*Staphylococcus hominis*

Case three non-sterile Surgeon B	*Bacillus megaterium, Bacillus altitudinis*
Case four non-sterile Surgeon B	*Bacillus megaterium, Staphylococcus epidermidis*

4 Discussion

Cataracts represent the most common form of blindness worldwide. In Western countries, the primary concern often revolves around prolonged waiting times for surgical procedures. In contrast, regions like Africa face a more pressing challenge—a critical shortage of qualified ophthalmologists.

This gap in specialized care means that many people in these countries remain untreated, leading to preventable blindness. In nations like Nigeria, where rapidly growing populations and limited healthcare infrastructure strain medical resources, the lack of access to eye care specialists becomes even more critical. The prevalence of blindness in Nigeria is nearly one percent, meaning that approximately 2.16 million people are blind. Of these, over 43% suffer from cataract disease, while an additional 9% are affected by uncorrected aphakia or complications resulting from couching (Babalola, 2011).

Studies from Nigeria show that the density of ophthalmologists is extremely low. In theory, one ophthalmologist is responsible for over 800,000 patients (Abubakar & et al., 2022).

The unequal distribution of healthcare resources in this region exacerbates the problem, making it essential to address both, the need for medical professionals and the barriers to timely treatment. In many situations, having even a limited number of medical professionals is essential, as their presence can significantly impact patient care. Efforts such as charitable organizations and mobile clinics play a vital role in expanding access to medical services for those in need. These organizations can play a vital role in bridging the gap by offering necessary treatments to those who would otherwise have no access to specialized care, particularly in rural or underserved areas.

For many years ophthalmologists from the organization "Sehen ohne Grenzen” have been actively involved in Nigeria, specifically in Ihitte Uboma, Imo State, in the southern part of the country.

However, effective interventions require meticulous planning. Locally, this includes patient acquisition, the procurement of essential materials, and the organization of

postoperative care. Additionally, European teams must carefully select medical supplies, such as lenses, and ensure the transportation of necessary surgical equipment.
And even in the most resource-constrained environments it is imperative that patients receive the highest possible standard of care. To ensure this, surgical teams should follow strict guidelines and protocols to maintain the quality of their procedures.
One of those guidelines is the AIOS guidelines, which provide comprehensive support for performing cataract surgeries under basic conditions (Lalit & et. al., 2022).
"Sehen ohne Grenzen" has long adhered to these principles and has documented their approach in their 2023 mission, incorporating supervision and guidance throughout the entire process (Faschinger, o.D.).

The Austrian surgeons are trying to comply with the AIOS guidelines as best as possible. And although hygienic conditions are simple, the Nigerian eye camp in Ihitte-Uboma largely meets the hygienic recommendations outlined in the "AIOS Guidelines to Prevent Intraocular Infections and Cluster Outbreaks After Cataract Surgery." The camp particularly shines in preoperative patient management and surgical preparation. However, when comparing all the recommendations of the AIOS guidelines with the local conditions, the following points can be noted:

First, contact procedures like biometry or tonometry are conducted on the day of surgery if necessary. The AIOS guidelines suggest not to use contact procedures on the day of operation. At the eye camp in Nigeria this will not be possible to fulfil, because patients arrive at the hospital on the day of surgery and have their final check directly before surgery.
Second, a pulse oximeter is suggested during all surgeries by the AIOS but is not currently used in Nigeria. This would be a cheap and meaningful addition in patient monitoring for future eye camps as a study for patients' safety confirms that a pulse oximeter is sufficient to monitor patients during cataract surgery and no intravenous line is needed (Duroi, Baudet, Bigoteau, Slim, & Pichard, 2021). A second study published in the Indian Journal of Anesthesia also highlights the importance of a pulse oximeter in local anesthesia to detect hypoxia (Divatia, 2011).
Third, for high-risk patients with three or more comorbidities, an anesthesiologist or an additional doctor should be present during surgery to monitor the patient, according to the guidelines. Due to the lack of personnel resources, only one Austrian surgeon is present

during operations, but Nigerian doctors are always within reach and ready to assist with critical cases.
Fourth, for scrubbing the surgeons' hands tap water is used. One recommendation may be to use purified drinking water, which can be purchased locally. However, it should be noted that surgeons wear sterile gloves during the entire procedure and never touch the patient's eyes with their bare hands.
Fifth, postoperative management is handled as recommended by the guidelines. After 24 hours one follow-up examination is conducted. However, additional voluntarily examinations cannot be performed, because the Austrian doctors have to leave after one week.

Two main points could be brought to light regarding the eye swab results: First, none of the eye swab results were sterile. But most of the pathogens found were either bacteria of the Staphylococcus family or Aerobic Bacillaceae. These two species exist mostly on human skin (Davis, 1996). As we received the results from the Nigerian laboratory, it could have occurred, that the one taking the swabs touched the eyelid along the edge while swabbing. Some other types of bacteria like *Enterococcus faecalis* or Proteus species could have occurred due to lack of patients´ hygiene. Many people in Nigeria live in rural areas and under basic conditions, some without electricity or running water and/or with poor water quality being a significant issue (Adesola RO, 2024) (Adamu I, 2022).
The issue of Antimicrobial Resistance (AMR) is indeed a growing concern, and it's particularly significant in countries like Nigeria where healthcare challenges can be compounded by limited resources. The fact that the WHO identifies AMR as one of the top global public health threats speaks to the urgency of addressing it (Isa, 2024).
As a second key point, the eye swab results show that Gentamycin was effective against all tested microorganisms and can continue to be used as a postoperative local antibiotic. However, the presence of MRSA in some eye swabs highlights the need for continuous monitoring.

Not entirely unexpected**,** the results of the water tests did not meet the Austrian drinking water standards. However, two samples showed surprising results: the bacterial growth values of two samples stayed within the limits, even though the water is not filtered inside the hospital but is simply pumped directly from the groundwater. Due to very acid water

conditions with all samples having a pH-value of around 4,5 it is likely that bacterial growth is inhibited. The book of Marisa Cases demonstrates the optimal growth conditions in terms of pH values for common types of bacteria. Most types are adapted to pH values around neutral (Cases, 2019). This is likely the reason why none of the coliforme bacteria, Enterobacterales or Pseudomonas are present. The local population is adapted more or less to the drinking water in Nigeria, but for foreigners it is not advised to consume it (Piyaphanee W, 2023).

One part of the AIOS guidelines is the inspection of the operating room and the equipment used, including the sterilization process. So, within this evaluation, surface samples were collected inside the operating theatre and outside in non-sterile areas. Inside the operating theatre most of the surfaces tested were sterile but some areas, for example both operating microscopes and one bedhead of the operating table were not sterile. Although only CNS (Coagulase-negative staphylococci) were found, their presence indicates that the head of the microscope comes into contact first and foremost with the surgeon's skin. To prevent the transfer of pathogens to the patient's eye, the microscopes should be cleaned after each surgery. On the other hand, cleaning and draping works out very well on both side tables for instruments and the second bedhead. Those samples were completely sterile.
All other surface samples were taken from non-sterile areas, especially areas with frequent hand contact. Special cleaning attention could be turned to the side table for the local anesthesia inside the examination room. A variety of pathogens have been found there, including Cunninghamella spp., Curvularia spp., CNS and Micrococcus spp. It must be noted that MRSA was also detected here.

The results of the swabs of the sterilizer showed that only one sample was in fact sterile. That means the sterilizers did not work properly at the time of taking the samples. As a result, they were replaced promptly and sent for servicing. As it is crucial to have sterile operating instruments to prevent intraocular infections, it would make sense to test and service the sterilizers regularly. Although not sterile, the pathogens found in the samples were, in this case, microorganisms typically found on human skin.

Overall, the results reflect the hygienic condition at this eye camp in Nigeria, but these samples are only a snapshot. Moreover, the team was only present for about one week,

meaning only a limited number of swabs or tests could be conducted. Therefore, periodic further investigations were one of the goals that were discussed.

5 Conclusion

During the annual stay of "Sehen ohne Grenzen", this hygiene evaluation was conducted. The investigations of the hygienic conditions align with the expectations of an eye camp held under rural conditions. Most standards of the AIOS guidelines that ensure a safe environment for cataract surgery were met. In cases where the requirements were not fulfilled, recommendations were proposed to the team to enhance the safety and comfort of both, patients and hospital personnel, in the future.

The lab tests provide a qualitative evaluation of the local hygienic conditions. The results of the eye swab samples confirm the importance of pre-operative disinfection to prevent post-operative endophthalmitis. Surface samples taken from the operating theater indicate that critical areas of the room were completely sterile, except for the surgeon's microscopes and the head part of one bed. Additionally, the analysis of the hospital's water quality reveals that while it meets local requirements for general use, it is not suitable for operative use or as drinking water for foreigners due to high bacterial contamination. Lastly, the malfunction of the sterilizers was reported to the team to ensure sterile instruments for future eye camps.

This thesis represents the first assessment of the hygienic situation, which is crucial to ensuring optimal treatment conditions for patients in Nigeria. It provides essential feedback for improving future eye camps, confirms that minimum requirements were met, and offers a survey of the microorganisms found inside the hospital. Ultimately, the results demonstrate that "Sehen ohne Grenzen" successfully upholds the operating standards under challenging conditions and provide an invaluable opportunity for the entire region to access ophthalmologic treatment.

6 Bibliography

Abubakar, I., & et al. (2022). The Lancet Nigeria Commission: investing in health and the future of the nation. *Lancet, 399*(10330), 1155-1200.

Adamu I, A. F. (2022). Availability of Drinking Water Source and the Prevalence of Diarrhea among Nigerian Households. *American Journal of Tropical Medicine and Hygiene*, 893-897.

Adesola RO, O. E.-P. (2024). Navigating Nigeria's Health Landscape: Population Growth and Its Health Implications. . *Environmental Health Insights.*, 18.

Asuquo, I., & et al. (2014). The dangers of couching in southwest Nigeria. *Malays J Med Sci, 21*(5), 60-5.

Babalola, O. (2011). The peculiar challenges of blindness prevention in Nigeria. *African Journal of Medicine and Medical Sciences*, 309-319.

Bale , B., Elebesunu, E., Manikavaagar, P., Agwuna, F., Ogunkola, I., Sow, A., & Lucero-Prisno, D. (2023). Antibiotic resistance in ocular bacterial infections: an integrative review of ophthalmic chloramphenicol. *Tropical Medicine and Health*, 15.

Burton, M., & et al. (2021). The Lancet Global Health Commission on Global Eye Health: vision beyond 2020. *Lancet Glob Health , 9*(4), e489-e551.

Cases, M. (2019). The Effects of pH and Temperature on Microbial Growth. In M. Cases, *Introduction to Microbiology* (pp. 365-371). Manchester: libre texts.

Chiang, M., & Chern, E. (2022, Aug). Ocular surface microbiota: Ophthalmic infectious disease and probiotics. *Front Microbiol, 13*, 952473.

Dancer, S. J. (2004, Jan). How do we assess hospital cleaning? A proposal for microbiological standards for surface hygiene in hospitals. *J Hosp Infect., 56*(1), 10-5.

Davis, C. (1996). Normal Flora. In B. Samuel, *Medical Microbiology.* Galveston.

Divatia, J. (2011). Pulse oximetry: Mandatory for sedation during regional/local Anaesthesia (but watch for hypoventilation!). *Indian Journal of Anaesthesia*, 217-219.

Duroi, Q., Baudet, J.-M., Bigoteau, M., Slim, M., & Pichard, T. (2021). Ambulatory cataract surgery centre without perioperative anaesthesia care: a prospective cohort study. *Scientific Reports*, 11.

Emeakaroha, E. (2013). *Madonna Austrian Hospital Ihitte*. Retrieved january 10, 2024, from http://www.emeka.at/v2/index.php/hilfsprojekte/spitalprojekt/allgemeine-information

EN ISO e.V. (Hrsg.). (2006). *EN ISO 19458:2006 Empfohlene und annehmbare Werte für maximale Probenlagerungszeiten, einschließlich Transportzeit und Temperatur, sofern in den speziellen Normen nicht anders angegeben.* Beuth.

Faschinger, M. (o.D.). *sehenohnegrenzen.org*. Retrieved from https://www.sehenohnegrenzen.org/index.php/2005/10/26/ueber-sehen-ohne-grenzen/

Iheanacho, C., & Eze, U. (2022). Antimicrobial resistance in Nigeria: challenges and charting the way forward. *Eur J Hosp Pharm, 29*(2), 119.

Isa, H. K. (2024, october 20). *Nigeria launches action plan to combat Antimicrobial Resistance (AMR)*. Retrieved from Nigeria launches action plan to combat Antimicrobial Resistance (AMR): https://www.afro.who.int/countries/nigeria/news/nigeria-launches-action-plan-combat-antimicrobial-resistance-amr#:~:text=Nigeria%20launches%20action%20plan%20to%20combat%20Antimicrobial%20Resistance%20(AMR),-20%20October%202024&text=Abuja%2C%2020%20Octobe

ISO e.V. (Hrsg.). (2018). *ISO 8199:2018 Water quality - General requirements and guidance for microbiological examinations by culture.* Geneva: ISO copyright office.

Kahlmeter, G. (2025, January 6). *The European Committee on Antimicrobial Susceptibility Testing - EUCAST*. Retrieved from The European Committee on Antimicrobial Susceptibility Testing - EUCAST: https://www.eucast.org/

Kumpel, E., & et al. (2016). Urban Water Services in Fragile States: An Analysis of Drinking Water Sources and Quality in Port Harcourt, Nigeria, and Monrovia, Liberia. *Am J Trop Med Hyg, 95*(1), 229-38.

Lalit, V., & et. al. (2022). All India Ophthalmological Society (AIOS) Task Force guidelines to prevent intraocular infections and cluster outbreaks after cataract surgery. *Indian Journal of Ophthalmology*, 4457-4458.

Moszkowicz, D., & et al. (2019, Oct). Operating room hygiene: Clinical practice recommendations. *J Visc Surg, 156*(5), 413-422.

Muhammad, N., & et al. (2017). Changing patterns of cataract services in North-West Nigeria: 2005-2016. *PLoS One, 12*(8), 0183421.

n. a. (2024). *Life Expactancy by Country and in the World (2024)*. Retrieved january 10, 2024, from https://www.worldometers.info/demographics/life-expectancy/

n. a. (2024). *Nigeria*. Retrieved january 10, 2024, from https://en.wikipedia.org/wiki/Nigeria

Nigeria?, w. i. (2024, n.d. n.d.). *what is the population of Nigeria?* Retrieved from what is the population of Nigeria?: https://www.theworldcounts.com/populations/countries/nigeria

Nizami, A., & Gulani, A. (2022). Cataract. In *Treasure Island.* StatPearls Publishing.

Piyaphanee W, S. R.-M. (2023). Healthcare seeking during travel: an analysis by the GeoSentinel surveillance network of travel medicine providers. *Journal of Travel Medicine*, 30.

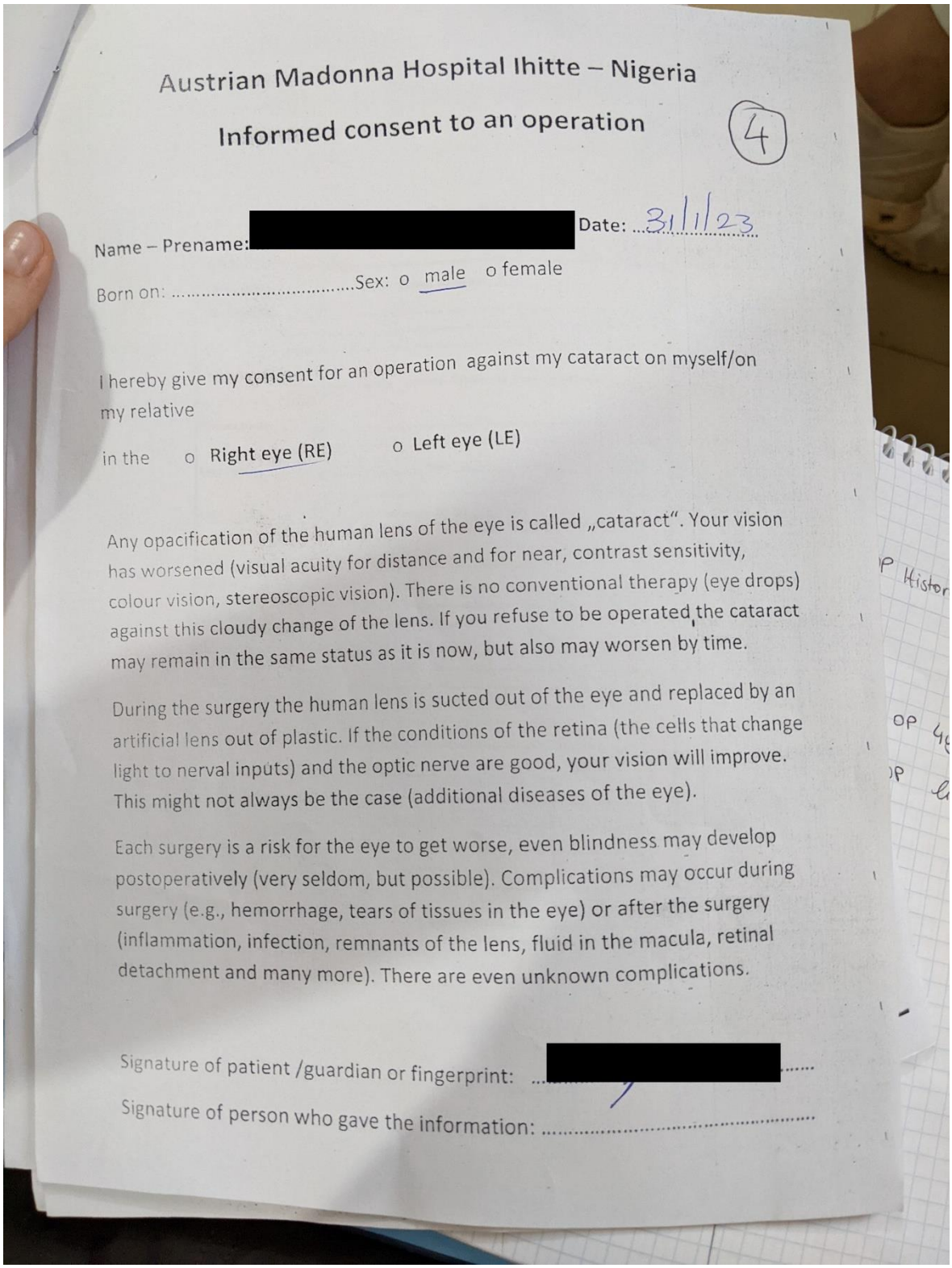
7 Appendix

Figure 6 Eye examination before surgery

Figure 7 Local anesthesia application

Figure 8 Operating theatre

Figure 9 Postoperative examination 24 hours after surgery



Austrian Madonna Hospital Ihitte – Nigeria

Informed consent to an operation

4

Name – Prename: [redacted] Date: 31/1/23

Born on: .....Sex: o male o female

I hereby give my consent for an operation against my cataract on myself/on my relative

in the o Right eye (RE) o Left eye (LE)

Any opacification of the human lens of the eye is called „cataract". Your vision has worsened (visual acuity for distance and for near, contrast sensitivity, colour vision, stereoscopic vision). There is no conventional therapy (eye drops) against this cloudy change of the lens. If you refuse to be operated the cataract may remain in the same status as it is now, but also may worsen by time.

During the surgery the human lens is sucted out of the eye and replaced by an artificial lens out of plastic. If the conditions of the retina (the cells that change light to nerval inputs) and the optic nerve are good, your vision will improve. This might not always be the case (additional diseases of the eye).

Each surgery is a risk for the eye to get worse, even blindness may develop postoperatively (very seldom, but possible). Complications may occur during surgery (e.g., hemorrhage, tears of tissues in the eye) or after the surgery (inflammation, infection, remnants of the lens, fluid in the macula, retinal detachment and many more). There are even unknown complications.

Signature of patient /guardian or fingerprint: [redacted]

Signature of person who gave the information: .....

Figure 10 Written informed consent

Figure 11 Water supply at the hospital

Figure 12 Water storage tower